

# METHODOLOGY FOR THE CONFIDENCE AND ACCURACY EVALUATION OF CALIBRATION PROCESSES

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## **Abstract:**

The aim of this technical paper is to present a generic methodology that could allow the analysis of the Dimensional Metrology Laboratory (LAMIN) measurement processes and verify if they present the necessary confidence and accuracy to the calibration activities performance. The motivation for the methodology development arose due to the difficulty to attend some technical requirements of the ISO/IEC 17025 standard [1], in special the 5.9, that talks about the “Assuring the Quality of Test and Calibration Results”.

It is presented a routine to be followed in its application to evaluate the quality of a measurement process. The methodology was tested and showed to be valid, assuring continuously the quality of the measurements performed in a metrology laboratory when applied periodically, following some established criteria.

## **Introduction:**

The National Metrology Institutes (NMI) have the commitment to disseminate the units of the International System of Units (SI) with the required metrological confidence to their services users, as well as to evidence technical competence, through the compatibility of results with their congeners, aiming the Mutual Recognition Arrangement (MRA) co-ordinated by the “Bureau International des Poids et Mesures” (BIPM). As the reference laboratory in the dimensional metrology area in the country, LAMIN from INMETRO (NMI from Brazil) has this commitment.

The main target of this work was to develop a formal methodology which could be applied to all the LAMIN measurement processes aiming a better performance, a re-evaluation of the measuring uncertainties and the continuous quality of its calibration services.

The methodology application allowed to develop the critical analysis sense related to the carried out calibration tasks, as well as to generate a guidance document to other metrology

laboratories. It was mainly based on the ISO/IEC 17025 [1] technical requirements and relevant concepts contained in the ISO/TS 14253-2 [2].

### Proposed methodology:

The proposed methodology steps to be followed are:

#### Step 1: Required accuracy determination

Before evaluating any measurement process, it is necessary to know its required accuracy or, in other words, to know its required measurement uncertainty.

It can be seen in the following figure that compliance and non compliance zones become smaller when the uncertainty becomes larger.

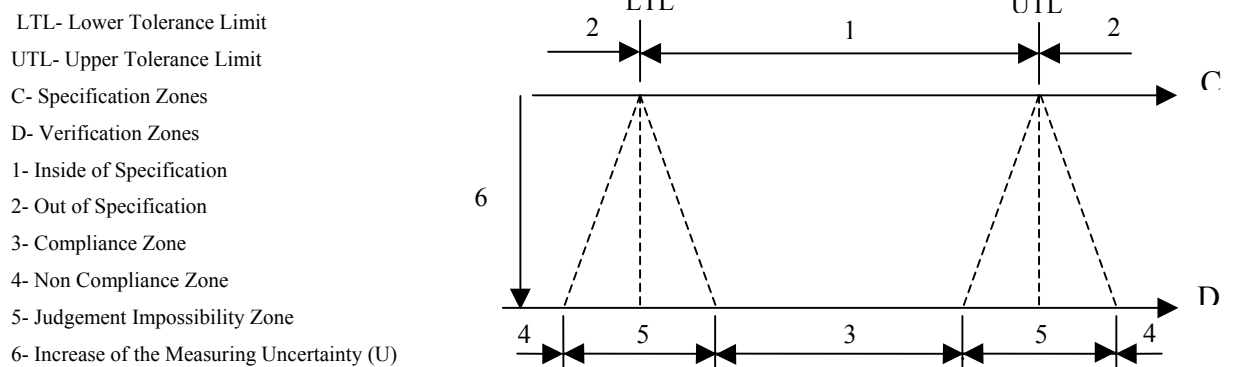


Fig. 1: Correlation between tolerance and measurement uncertainty (ISO 14253-1, 1998) [3]

#### Step 2: Measurement conditions analysis

The measurement conditions can be divided into three.

They are: installations, environment conditions and human resources

It is reasonable, before the measurement method or procedure evaluation, to check the measurement conditions. If they have to be modified, it can be possible to improve the confidence in the measurement process, not being necessary to modify its method or procedure. Promoting modifications on the measurement conditions and concluding that it is not needed to modify the measurement method or procedure, the measurement results calculation, as well as the considerations about the measurement uncertainty, its mathematics model, its components and its calculation should be re-evaluated.

#### Step 3: Measurement principle, method and procedure analysis

After the required accuracy and measurement conditions evaluation, it is necessary, as a consequence of the measurement method and procedure critical analysis, to modify this last

one or to propose a new one, aiming the measurement process improvement. In both cases, it is necessary to define the measurement conditions to perform the calibration and, after that, to re-evaluate the measurement results calculations, as well as the considerations about the measurement uncertainty, its mathematics model, its components and its calculation.

#### Step 4: Measurement uncertainty analysis

Every influence quantities which can affect the measurement result should be considered in the mathematics model. After the mathematics model definition, the influence of each uncertainty component on the measurement uncertainty to be obtained should be analysed. Due to this analysis, it can be reasonable to reduce the influence of one of these components to reach the desired uncertainty by the client or by the own laboratory.

#### Step 5: Evaluation of the measurement processes quality

It can be done through the participation on inter and intra-laboratory comparison programs, repeated calibrations or re-calibration of clients items, services performance analysis, evaluation of the clients satisfaction, reference standards long term stability analysis and the historic of a client item results.

#### **Methodology synthesis and its application:**

This methodology should be applied periodically to the calibration processes in the following situations:

There is suspicion related to metrological techniques, to mathematics or statistics resources used to calculate measurement results and to the confidence on them; the laboratory measurement uncertainties not attend the clients or their own needs due to be large; the obtained measurement uncertainties not be in the same level of the uncertainties declared by other NMI from SIM, due to be very large; not compliance in inter-laboratory comparisons between LAMIN results and other NMI; not compliance between results in intra-laboratory comparisons; not consistence in a measurement process, as for example, not repeatable results, not reproducible results or with low accuracy, generating a large measurement uncertainty; the LAMIN obtained measurement uncertainties to be much lower than the desired measurement uncertainties, making the processes very expensive; and the technical standards used as reference for the measurement procedure preparation were revised and make necessary their revision.

The figure 2 shows the authors proposed sequence for the measurement processes analysis [4].

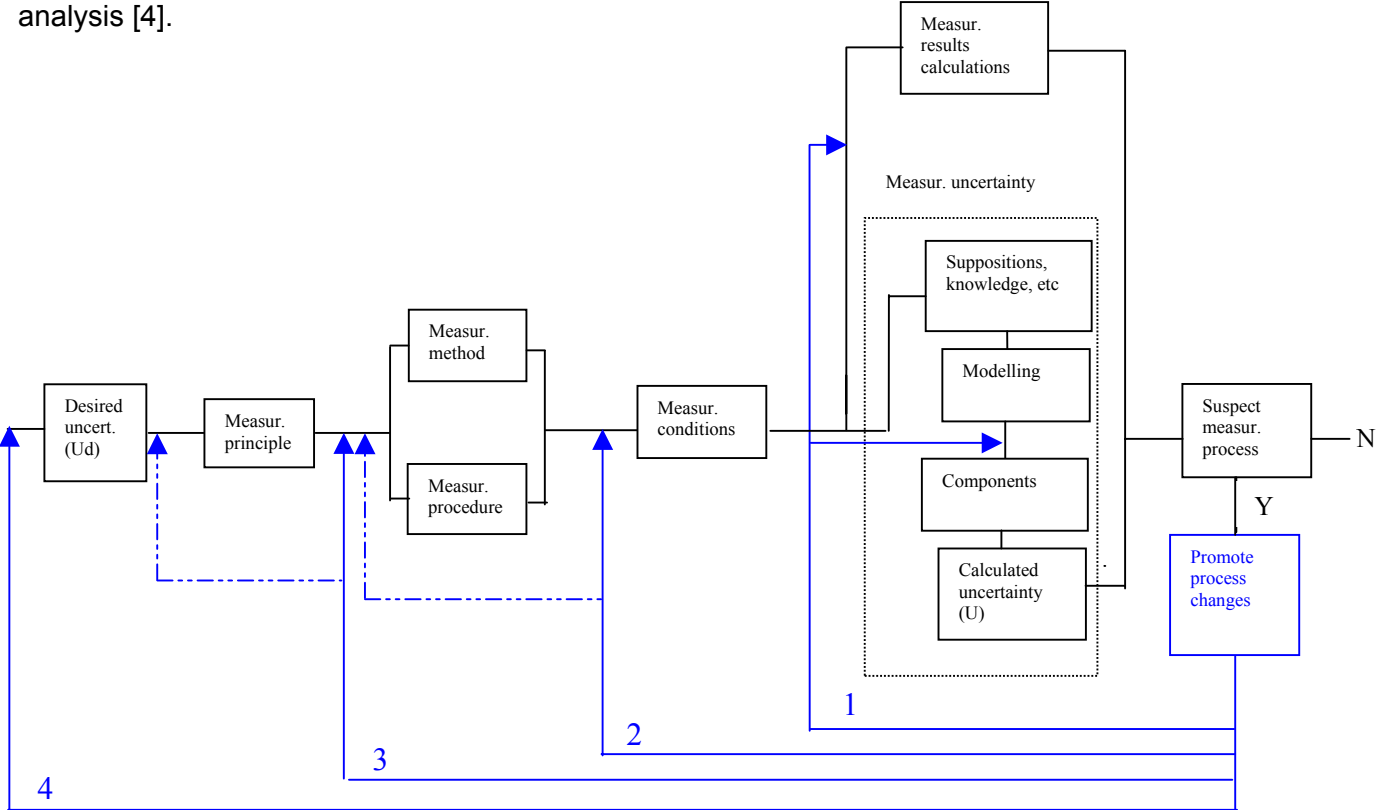


Fig. 2: Suspected measurement process analysis

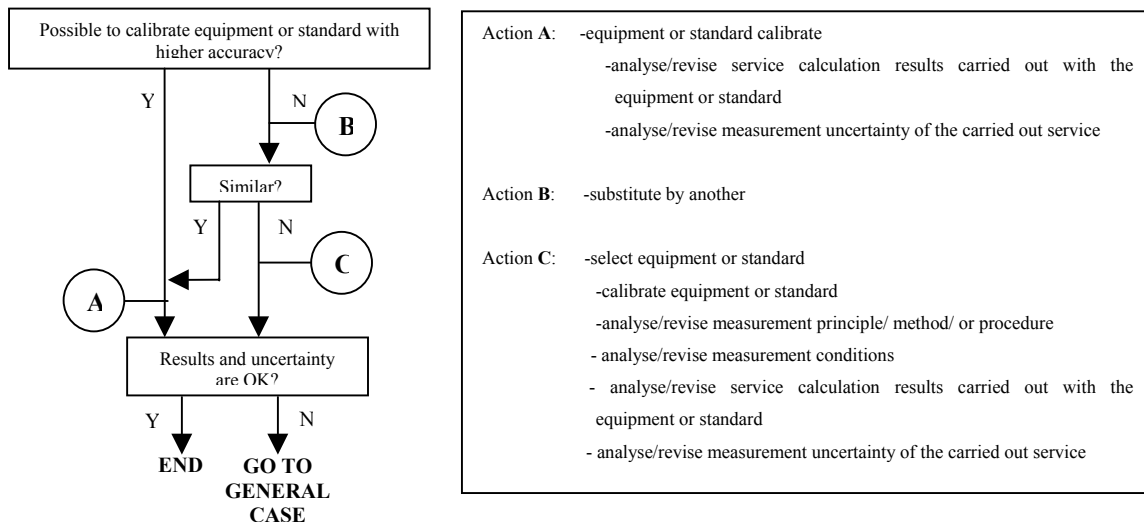
If in a measurement process the reference standard or measurement equipment used is suspected, being the solution its re-calibration or its substitution by a similar one, the interference in the process should be where is indicated by the arrow 1, in the figure 2. If the measurement results and uncertainties obtained in calibrations carried out with that standard or equipment are good enough, the analysis should be finished. If not, the measurement conditions should be evaluated, as indicated by the arrow 2, continuing up to the end.

In case of being necessary to interfere in the process without having a possible suspicion where the problem is, the measurement conditions should be analysed first, as indicated by the arrow 2, as well, continuing up to the end. If the measurement results and uncertainties are not good enough, the interference in the process should be as indicated by the arrow 3, re-evaluating the method and procedure. This can lead to a change in the measurement principle.

If the problem is not solved, the alternative is to re-evaluate the desired uncertainty (arrow 4).

**Actions to be implemented flowcharts:**

1) Suspicion: not consistent calibration or large uncertainty of the used measurement equipment or standard (particular case) [4]



2) Suspicion: Not identified (general case) [4]

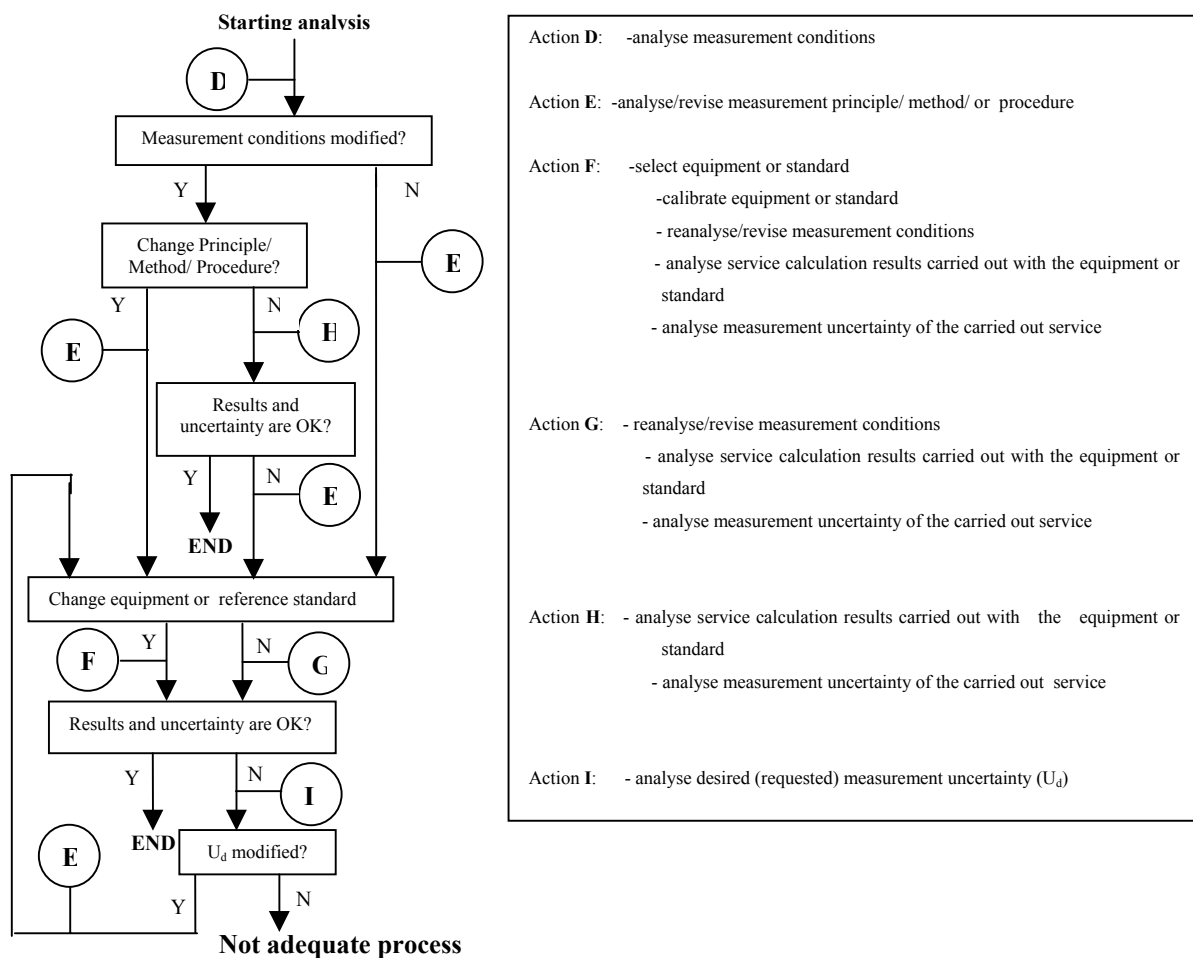


Fig. 3: Flowcharts of actions to be implemented

**Main conclusions:**

The methodology here presented is very useful for a metrology laboratory because through the formal processes critical analysis it is possible to detect failures on them and implement the necessary changes aiming their improvement.

The methodology was applied to a case study in plane angle metrology area and proved its efficiency, because it took account all factors which can affect a measurement process and lead to a not reliable measurement results.

**References:**

- [1] NBR ISO/IEC 17025: General requirements for the competence of testing and calibration laboratories. Rio de Janeiro, 2001
- [2] ISO/TS 14253-1: Geometrical Product Specifications (GPS)- Inspection by measurement of workpieces and measuring equipment. Part 1: Decision rules for proving conformance or non-conformance with specifications. 1st. ed. Switzerland, 1998
- [3] ISO/TS 14253-2: Inspection by measurement of workpieces and measuring equipment. Part 2: Guide to the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification. 1st. ed. Switzerland, 1999
- [4] Oliveira, José Carlos Valente de: Continuous and systemic guarantee of the quality in the calibrations carried out by the Dimensional Metrology Laboratory from Inmetro: implementation of a methodology proposal. Dissertation (Professional Master Science Course in Management Systems) – Laboratory of Technology, Business and Environment Management. Niterói: Universidade Federal Fluminense, 2004
- [5] CIPM Mutual Recognition of National Measurement Standards and of Calibration and Measurement Certificates issued by National Metrology Institutes. BIPM, France, 1999
- [6] EA-4/02: Expression of the measurement uncertainty in calibration. 1st. ed. Rio de Janeiro: INMETRO, ABNT, SBM, 1999
- [7] EA-2/03 (Rev. 01): EA Inter-laboratory Comparison. 1st. ed., 1996
- [8] ISO Guide to the Expression of Uncertainty in Measurement. ISO GUM. 1st. ed. Switzerland, 1995
- [9] Natrela M. G.: Experimental statistics. National Bureau of Standards (NBS) Handbook 91, 1963
- [10] Oliveira, José Carlos Valente de; Vieira, Luiz Henrique Brum; Souza, Marcos Motta de. Traceability chain and dissemination of angle measurements in Brazil. VIII International Metrology Congress. Besançon, 1997

